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論文名	「Content-Based Copy Detection for Copyright Protection of Line Drawings (線画の著作権保護のための内容に基づく複製検出)」
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### 論文要旨

Line drawing is a kind of image which consists of lines in few color placed against a plain background. Such as logos, diagrams and comics, line drawings have a large portion in the field of image publications. Therefore, there is a great requirement for their copyright protection. In this research, I focus on the most popular line drawings, manga, and propose methods to detect kinds of copies for their copyright protection.

The term “manga”, which is derived from the Japanese word, describes a kind of narrative artwork expressed by sequential comics and print cartoons. Normally, a certain manga series consists of multiple volumes containing several hundred manga pages. Objects in manga are mainly drawn with lines, but tones and word balloons elaborating the story lines are also employed. The modern style of manga developed in Japan in the late 19th century. In its short history, it has developed quickly to become one of the most popular types of image publication in the world. Especially in Japan, manga occupies a pivotal position in the publishing industry. The profitability of manga is not only confined to the sales of manga publications; revenues from other areas like advertisements and animation films using manga characters are also significant.

In actuality, the determination of what constitutes an illegal copy is a controversial problem and always depends on the judgment of professionals. However,

the huge volumes of manga publications require copyright protection, and it is impossible for human beings to check all manga pages manually. The purpose of our research is to apply computer techniques to detect candidate images for professionals' further judgment.

To detect copies of manga, we follow the Content-Based Copy Detection (CBCD) approach, in which a database is built based on copyrighted images and suspicious images are treated as queries. By retrieval of similar contents, the illegal copies will be reported with the information of their violated originals as evidence.

For making copies, the illegal users always use the original images with various changes, which make their copy detection difficult. With respect to their sources, copying of manga is divided into two types: (1) exact copies, which duplicate specific contents of manga, such as scanned manga publications (printed copies) and traced outlines of manga (hand-drawn copies), (2) similar copies, which are created by copying the features of the main objects. As an important part of manga, cartoon characters are always copied in this way. In addition, since there are numbers of series of manga requiring copyright protection, the burden of the database is also a problem for a practical system. For these problems, we offer the solutions to different problems in this thesis and apply real manga publications as experimental data to prove the effectiveness of the proposed methods.

This thesis is organized as follows.

Chapter 1 is the introduction of this research.

In Chapter 2, we focus on the problem of exact copies and propose a method using local feature matching for the partial copy detection. For making the copies, illegal users do not only copy the original directly, but always focus on certain interesting parts and make partial copies. Besides printed copies which are created by scanning printed images, hand-drawn copies can also be created by tracing the main lines of the originals. Furthermore, partial copies are often included as parts of other images, which make the detection more difficult. To detect the partial copies, local feature matching methods are widely utilized. Among kinds of local features, Scale-Invariant Feature Transform (SIFT) features show high performance for the retrieval of ordinary images. Based on our previous researches, SIFT is also available for detecting printed copies of line drawings. However, since the hand drawing changes the lines in detail, SIFT loses its effectiveness for hand-drawn copy detection. For this problem, we propose a robust feature for hand-drawn copy detection. Specifically, we focus on the regions enclosed by lines, which are relatively stable even if the lines change in detail, and apply Histogram of Orientation Gradients (HOG), an effective

feature descriptor for handwriting recognition, to describe the regions. In addition, for the copyright protection of large scale images, we studied methods to reduce the database and speed up the detection. Based on a database containing 10,009 manga pages, we proved the effectiveness of the proposed method for detecting both printed and hand-drawn partial copies from complex backgrounds.

Chapter 3 describes studies on the similar copy detection of cartoon characters. By copying features of cartoon characters, similar copies are created to express the same characters but with different descriptions, such as facial expressions, viewpoints and poses. To detect similar copies of cartoon characters, we propose a method based on Region of Interest (ROI). In this research, as an essential part of cartoon characters, face regions are treated as ROIs and detected by an object detection method. Then, the detected cartoon characters of suspicious images are recognized by matching with similar ones in the database. Because of the low discriminative face regions for cartoon characters, the recognition is not always successful if it is based only on features from face regions. For this problem, we proposed Concentric Multi-Region (CMR) model to explore significant features around face regions by the AdaBoost algorithm. In the experiments, images of 17 labeled cartoon characters were applied. Compared to some high-performance face and object recognition methods based on face regions, the proposed method shows higher performance for the recognition of cartoon characters

Chapter 4 is the study on series retrieval of serial publications. Since there are many series of manga requiring copyright protection, the burden of database is a problem that hampers the proposed copy detection method being used in practice. As a solution, we propose to retrieve the series of the queries, and then, concentrate on the database of the series, by which many efficient applications can be achieved. The series retrieval is based on the Bag-of-Features (BOF) model. The features from face regions of cartoon characters (proposed in Chapter 3) and discriminative generic regions (proposed in Chapter 2) are applied as visual words. Based on features from suspicious images, their series will be reported. The proposed method is not only available for serial manga, but also for other serial publication. In the experiments, we tested the proposed method for retrieval of manga pages and animation fragments. In addition, the proposed method was also proved to have the effectiveness for retrieving unreleased publications by using the released ones.

Chapter 5 is the conclusion of this thesis.

審査結果の要旨

本論文は、内容に基づく複製検出と呼ばれる手法を用いた線画の著作権保護に関する研究成果をまとめたものであり、以下の成果を得ている。

- (1) 図面、ロゴなどの様々な線画の中で、漫画の著作権保護は極めて重要な課題であることを述べるとともに、そのためには、一部分を切り取ったり、それを手書きでトレースしたりするタイプの複製（原本複製）、ならびに漫画キャラクターの特徴をまねて類似した線画を作成するタイプの複製（類似複製）の2つに対処しなければならないことを指摘した。方法としては、著作権を保護する漫画をデータベースに格納し、疑わしい画像を検索質問として与えることによって、類似した内容を持つ漫画をデータベースから検索するという、内容に基づく検索が有望であることを明らかにした。
- (2) 原本複製に対処するには、手書き複製によって加えられる様々な変形に対処しなければならない。画像検索に従来から用いられている **SIFT (Scale-Invariant Feature Transform)** と呼ばれる特徴量はこの変形に対して無力であり、**HOG (Histogram of Oriented Gradients)** と呼ばれる特徴量記述法と **MSER (Maximally Stable Extremal Regions)** と呼ばれる領域検出法を組み合わせることが効果的であることを実験的に検証した。
- (3) 類似複製に対処する手法として、漫画キャラクターの顔に関する興味領域、ならびに一般の特徴的な領域に関する興味領域の2つに基づく手法を提案した。特に、顔興味領域の記述のために、**Concentric Multi-Region (CMR)** モデルを新たに提案し、実験的に有効性を検証した。
- (4) 上記の2手法の計算量に関する問題に対処するため、漫画の画像を入力とし、その漫画がどのシリーズのものであるのかを分類する手法を考案した。これにより、上記2手法の適用範囲をデータベース中の全画像から同じシリーズのものに削減できるため、高速化が可能となった。

以上の諸成果は、線画の内容に基づく検索に対して、柔軟かつ高速な手法を実現するものであり、線画の著作権保護に貢献するところ大である。また、申請者が自立して研究活動を行うのに必要な能力と学識を有することを証したものである。